

Properties of cat mutually pumped phase conjugation and two-wave mixing gain in doped KNSBN

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Received May 16, 2003

Cat mutually pumped phase conjugation configuration is discovered and investigated by using two-wave mixing in $(K_yNa_{1-y})_{2z}(Sr_xBa_{1-x})_{1-z}Nb_2O_6$ (KNSBN) crystal. When only one signal or pumped beam does not give birth to phase conjugation, the maximum reflectivity of signal and pumped beam attain 140% and 30% due to two-wave mixing, respectively. The experimental results show that the two-wave mixing can reduce the threshold of incident beams power, extend the incident angle range, and shorten response rate in the process of self-pumped phase conjugator (SPPC) in KNSBN crystal.

OCIS code: 190.0190.

Self-pumped phase conjugators (SPPCs) using the total internal reflection from the crystal corner, without external mirrors, was first demonstrated in BaTiO₃ crystal by Feinberg^[1]. Feinberg's geometry was also referred to as Cat SPPC. Since then, a variety of different geometry had been discovered and invented in many kinds of photorefractive (PR) crystals, such as Sr_{1-x}Ba_xNb₂O₆ (SBN), KNbO₃, KTN, $(K_yNa_{1-y})_{2z}(Sr_xBa_{1-x})_{1-z}Nb_2O_6$ (KNSBN), GaAs, and InP etc. And no less than eight different configurations of mutually pumped phase were demonstrated in a variety of PR crystals to our knowledge^[2-18].

KNSBN crystals belonging to the tungsten bronze family have received much attention because they are easy to grow and have large PR nonlinearities. In addition, since they have low degrees of lattice occupancies, PR species and responses can be controlled by dopants into their lattice sites, and no phase transition at room temperature. High-gain two-beam coupling and efficient self-pumped phase conjugation have been demonstrated in KNSBN crystals with fully filled structures and with partially filled structures doped with Cu, Cr, Ce, Ti and Mn. Superior holographic storage performance in Co-doped KNSBN has also been demonstrated recently. In this paper, we investigated the characteristics of Cat SPPC and Cat mutually pumped phase conjugation similar Cat SPPC optical path in KNSBN crystal.

The PR crystal used in the experiment was $(K_{0.5}Na_{0.5})_{0.2}(Sr_{0.61}Ba_{0.39})_{0.9}Nb_2O_6$ grown by Czochralski method. It was doped with 0.05 wt.-% CeO₂. The sample was processed into $5.9 \times 7.4 \times 7.8$ mm³ rectangular parallelepiped shape with the *c*-axis along 7.8 mm edge. A CW He-Ne laser at 632.8 nm with 30 mW was used in our experiments as shown in Fig. 1. Extraordinary polarized beams were used in all experiments. The signal-beam (*I*₁) diameter was reduced compared to the one of the pumped beam (*I*₂) by passing through two pinholes to ensure a good overlap between the two beams. Furthermore, the intensity of the signal beam was much less than the one of the pumped beam (a factor of 80) in order to be in the undepleted pump approximation. The forward two-wave mixing gain coefficient Γ was measured by monitoring the intensities of the transmitted

signal beam without (*I*'₁) and with (*I*''₁) illumination by the pump beam, which is defined as^[19,20]

$$\Gamma = \frac{1}{d} \ln \frac{I''_1}{I'_1}, \quad (1)$$

where *d* is the length of the two interactive beams and corresponds to the thickness of the crystal. Figure 2 shows the Γ corresponding to the different incident angles 2θ . We can see that the largest Γ is about from 80° to 110° which is not different comparing to the previous experimental results. With increasing two-wave coupling

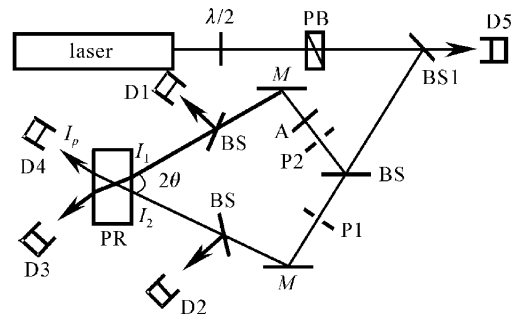


Fig. 1. Experimental setup. $\lambda/2$: half-wave plate; PB: polarizing beam splitter; M: mirror; BS: beam splitter; P: pinhole; D: photodetectors; A: attenuator; PR: photorefractive.

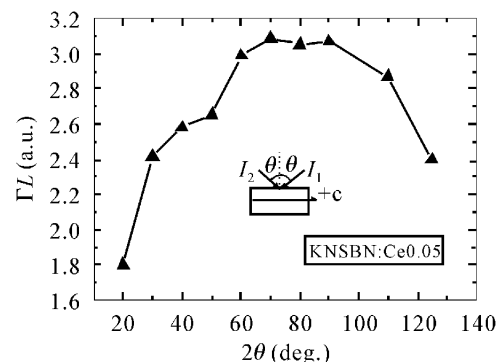


Fig. 2. ΓL of forward two-wave mixing as a function of 2θ between beams *I*₁ and *I*₂.

time, the gain of signal beam would quickly descend even produce negative gain. MPPCs of two beams gradually produce and increase with descending the gain of single and the diffraction efficiency of pumped beam at the same time.

In our experiment, one signal beam or one pumped beam does not produce SPPC in long times (exceed one hour) due to signal beam power and the degree between pumped beam and incident face without attaining threshold. The characteristics of SPPC are shown in Figs. 3 and 4. From Fig. 3, we can see that the reflectivity of SPPC was about half the maximum reflectivity when incident pumped beam is no more than 0.5 mW, and find that the response time of SPPC was 1–2 hour when incident pumped beam is no more than 2 mW. The SPPC was not found when incident pumped beam power is 0.1 mW and the time is no less than 2 hour. So the SPPC threshold of incidental beam is about 2 mW and incidental angle $\theta > 0^\circ$ (see Fig. 4) in this experimental sample.

Figures 5(a), (b) and (c) show the characteristics of two-wave mixing gain and MPPC reflectivity in KNSBN crystal. From Fig. 5, we can see that the respond time of two-wave mixing gain is quicker than that of MPPC. In stable stage, the largest MPPC reflectivity and the smallest two-wave mixing gain can be found simultaneously even if the experiment acquires small wave. It is shown that the higher value of MPPC reflectivity and quicker response time are propitious to the incident angle 2θ in the experiments.

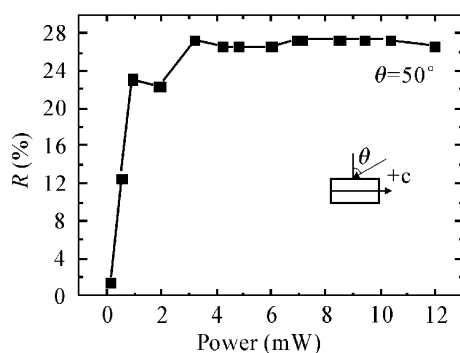


Fig. 3. The phase conjugation reflectivity of the SPPC corresponding to the different incident beam power in KNSBN:Ce crystal.

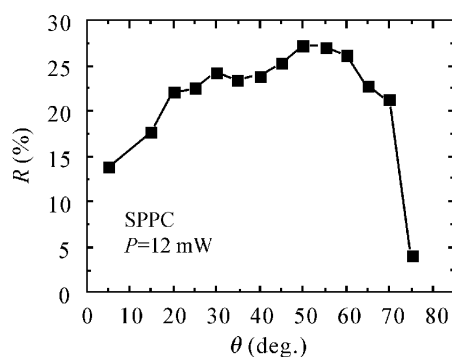


Fig. 4. The phase conjugation reflectivity of the SPPC corresponding to the different incident angle in KNSBN:Ce crystal.

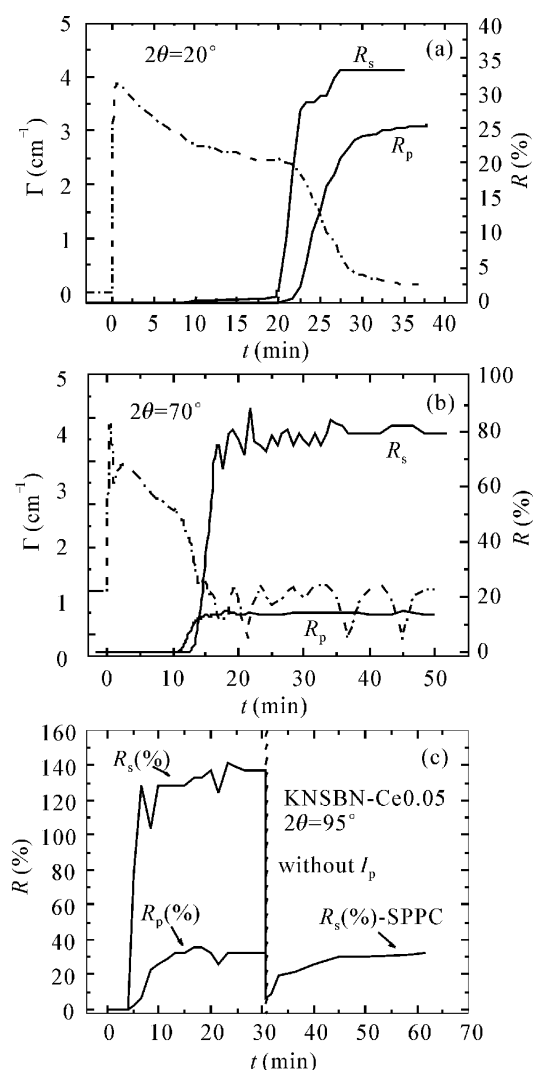


Fig. 5. (a) $2\theta = 20^\circ$, (b) $2\theta = 70^\circ$, two-wave mixing gain Γ and two beam MPPC reflectivity R as a function of time; (c) $2\theta = 95^\circ$, two beam MPPC and SPPC reflectivity R as a function of time.

The SPPC reflectivity of signal beam was increasing from the lowest to the highest when the pumped beam was shut (see Fig. 5(c)). The highest reflectivity was no less than 30% in the incident angle $2\theta = 95^\circ$. This experimental result indicated that the Cat MPPC was propitious to the SPPC, which meant that the pumped beam may be as a switch to control weak signal beam giving birth to SPPC.

It is well-known that two-wave mixing constant increase with the increasing of incident angle and the energy transfer direction is formed toward the c -axis under the experimental conditions^[21]. This means that the forward two-wave mixing (FTWM) gain is increased gradually with the increasing of incident angle 2θ . And more and more energy is transferred from pumped beam I_2 (or I_p) to signal beam I_1 (or I_s), and from incident beam to forward scattering in FTWM.

Photograph of the optical path pattern inside the KNSBN:Ce is shown in Fig. 6, which indicates that the optical path pattern of two beams MPPC is similar to

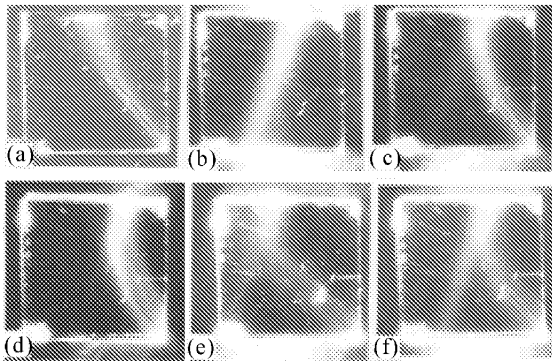


Fig. 6. Photograph of the optical path inside the KNSBN:Ce. (a) SPPC $\theta = 45^\circ$, incident beam $I=12$ mW; (b) initial stage; (c) steady state two incident beam MPPC; (d) and (e) different incident spot in steady state $2\theta = 95^\circ$; (f) without signal beam when (c) steady state.

that of Cat SPPC. The above result have demonstrated that two beams MPPC is not only the lowest threshold, but also the largest phase conjugative reflectivity comparing to SPPC in KNSBN crystal.

This work was supported by a grant from the Key Research Project No. 2 in the Climbing Program from the State Science and Technology Commission of China, and partially supported by the Young National Science Foundation of Shandong University. X. Xu's e-mail address is xgxu@icm.sdu.edu.cn.

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